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Air-to-Air Missile T&E Using Live Aircraft Linked to a Missile HWIL Simulaiton

By: Dr. Larry McKee

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Joint Advanced Distributed Simulation
Joint Test Force
2050A 2nd St. SE
Kirtland Air Force Base, New Mexico 87117-5522

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Air-to-Air Missile T&E Using Live Aircraft Linked to a Missile HWIL Simulation

By Dr. Larry McKee
Science Applications International Corporation, JADS JTF, Albuquerque, New Mexico

ABSTRACT

The Live Fly Phase (LFP) of the Systems Integration Test (SIT) was executed by the Joint Advanced Distributed Simulation (JADS) Joint Test Force (JTF) and the 46th Test Wing at Eglin AFB, FL during 1997. The purpose of the SIT was to evaluate the utility of using advanced distributed simulations (ADS) to support cost-effective testing of an integrated missile weapon/launch aircraft system in an operationally realistic scenario. The SIT missions simulated a single shooter aircraft launching an air-to-air missile against a single target aircraft.

In the LFP, the shooter and target were represented by live aircraft and the missile by a simulator. ADS techniques were used to link two live F-16 fighter aircraft flying over the Eglin Gulf Test Range to the Advanced Medium Range Air-to-Air Missile (AMRAAM) AIM-120 hardware-in-the-loop (HWIL) simulation facility at Eglin. This configuration had both DT and OT characteristics. There was a DT flavor because an HWIL facility was used to simulate the missile. This allowed the detailed performance of missile subsystems to be monitored, typical of a DT test. The OT characteristics of the LFP resulted from the use of aircraft performing operationally realistic engagements. Two baseline scenarios were selected from the AMRAAM FOT&E(2) live fire test series and modified for replication in the LFP trials.

There were four major test objectives of the LFP:

(1) Assess the validity of AMRAAM data generated in the LFP ADS configuration.
(2) Assess the ability of the LFP ADS configuration to perform AMRAAM testing.
(3) Assess the ability to link live aircraft to a missile HWIL simulation.
(4) Evaluate the ability of the LFP ADS configuration to support distributed missile testing.

This paper describes the LFP testing that was conducted during 1997, presents the results from evaluating the test objectives, and summarizes the utility of the LFP ADS configuration for air-to-air missile T&E.

LFP OVERVIEW

The LFP was executed by the JADS JTF and the 46th Test Wing at Eglin AFB, FL during 1997. The SIT missions simulated a single shooter aircraft launching an air-to-air missile against a single target aircraft. The scenarios utilized in the LFP missions were based on previous AMRAAM testing and are shown in Figure 1. These scenarios were modified somewhat to accommodate testing limitations and were replicated during LFP testing.

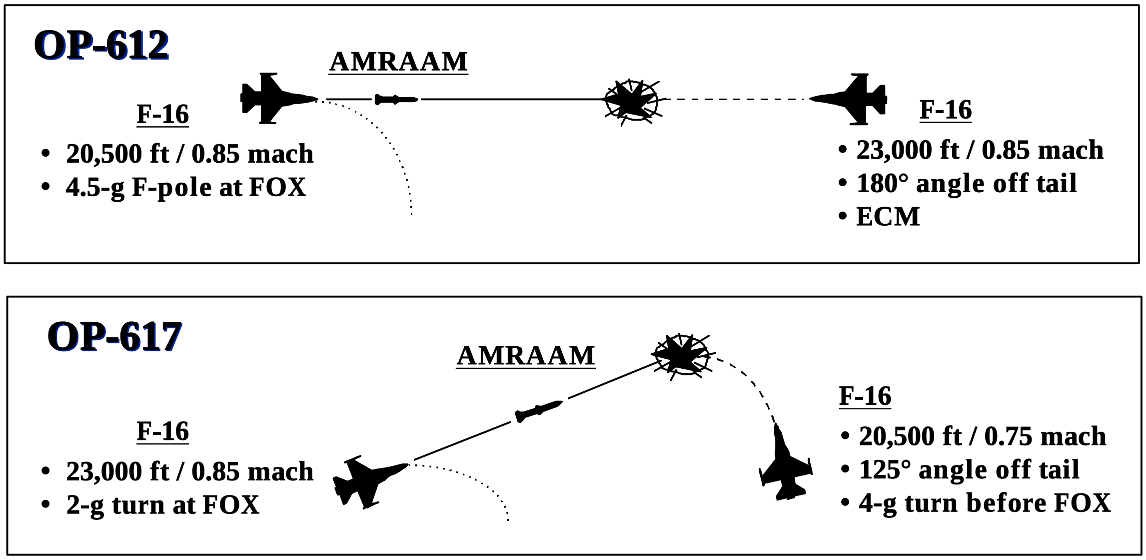

Figure 1. AMRAAM Live Fire Profiles (FOT&E(2), 14 September 93 and 9 July 93)

In the LFP, the shooter and target were represented by live aircraft and the missile by a simulator. ADS techniques were used to link two live F-16 fighter aircraft flying over the Eglin Gulf Test Range to the AMRAAM AIM-120 HWIL simulation facility at Eglin. The LFP test configuration is shown in Figure 2.

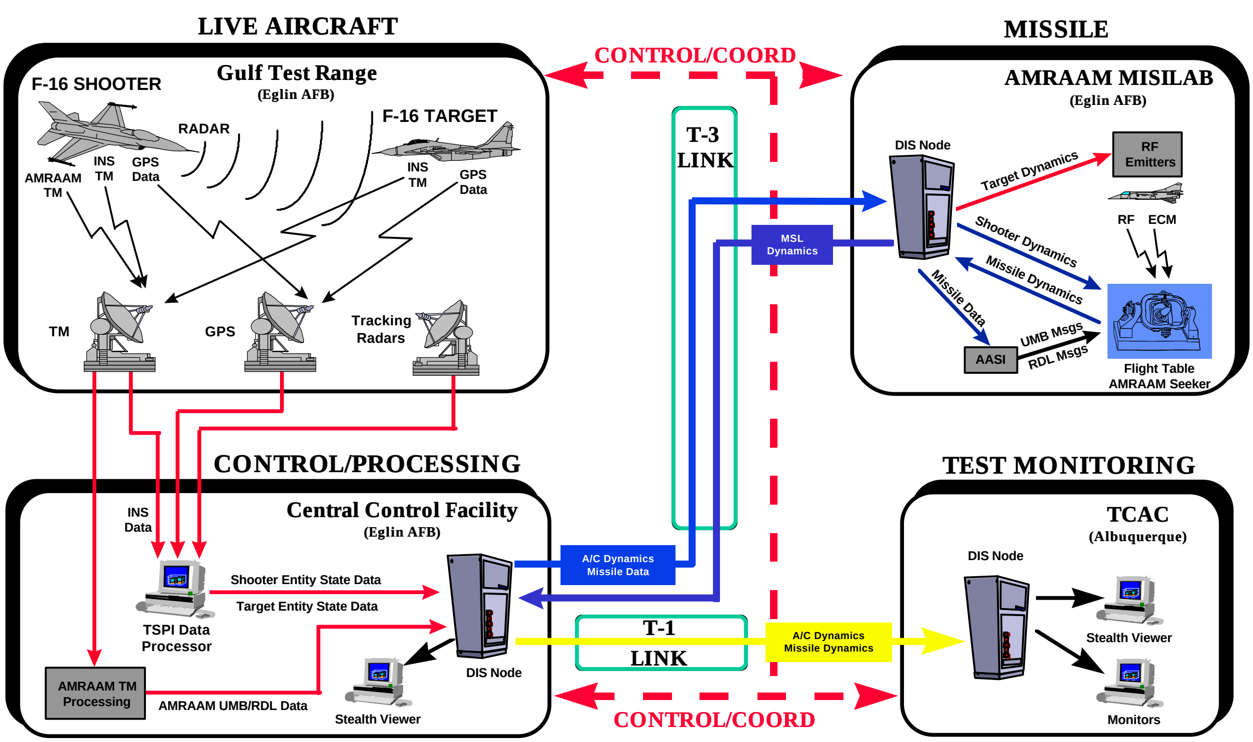

Figure 2. Live Fly Phase Test Configuration

Global Positioning System (GPS) and telemetry data were downlinked from the aircraft and passed to the Central Control Facility (CCF) at Eglin. GPS, inertial navigation system (INS), and tracking radar data for each aircraft were combined by the TSPI Data Processor (TDP) in the CCF to produce optimal entity state solutions. The aircraft entity state data were transformed into Distributed Interactive Simulation entity state protocol data units (DIS ES PDUs) and transferred to the AMRAAM HWIL laboratory at the MISILAB over a T-3 link. The shooter aircraft "fired" the AMRAAM in the MISILAB at the target and provided umbilical and rear data link (RDL) updates of the target position and velocity to the missile during its launch and flyout. The AMRAAM seeker was mounted on a flight table and responded to radio frequency (RF) sources in the MISILAB which simulated the seeker return from the target, the relative motions of the target and the missile, and electronic countermeasures (ECM). A T-1 link between the CCF and the JADS Test Control and Monitoring Center (TCAC) allowed JADS personnel to monitor the simulated intercepts.

The actual umbilical and RDL messages from the shooter aircraft were used to initialize, launch, and update the missile in the MISILAB during each simulated engagement. The shooter carried a pod which emulated the AMRAAM missile in its pre-launch configuration, and AMRAAM telemetry from the pod was downlinked and processed by the CCF. The telemetry was converted into DIS PDUs and transferred to the MISILAB over the T-3 link. The messages were then reconstructed and synchronized to the aircraft TSPI data by the Advanced Aircraft Simulation Interface (AASI) in the MISILAB.

The test runs were controlled from the CCF. The control center ensured that all players were ready for each run and issued the commands to start and stop the passes. PDUs were processed at the TCAC to provide JADS personnel with real-time stealth node viewing of the simulated engagement.

LFP TEST OBJECTIVES

The LFP was designed to examine the relationships between network performance, system under test (i.e., AMRAAM) data, and test measures of interest. The test objectives were:

- Objective 1: Assess the validity of AMRAAM data obtained in the LFP ADS configuration.
- Objective 2: Assess ability of LFP ADS configuration to perform AMRAAM testing.
- Objective 3: Assess ability to link live aircraft to missile HWIL simulation.
  - (This test objective was broken into subobjectives as follows.)
  - Subobjective 3-1: Assess ability to provide required TSPI accuracy.
  - Subobjective 3-2: Assess ability to provide required reference frame alignment.
  - Subobjective 3-3: Assess ability to provide required data synchronization.
  - Subobjective 3-4: Identify and quantify latency of LFP ADS configuration.
- Objective 4: Assess ability of LFP ADS configuration to support AMRAAM testing.
  - (This test objective was broken into subobjectives as follows.)
  - Subobjective 4-1: Assess capability of network to provide required bandwidth and connectivity.

Subobjective 4-2: Assess the effects of ADS-induced errors on LFP test results validity.
Subobjective 4-3: Assess adequacy of standard data protocols for LFP test.
Subobjective 4-4: Assess reliability, availability, and maintainability of ADS network.
Subobjective 4-5: Assess capability for centralized test control and monitoring.

LFP TEST RESULTS

Testing was performed during the following periods:

- Live Risk Reduction Missions. Four risk reduction flight missions were performed between March and July 1997. These were used to buildup and verify the LFP configuration.
- Formal Live Mission. One formal mission was conducted on 11 September 1997.
- MISILAB Standalone Runs. Monte Carlo runs were performed in which data recorded from the live mission were replayed into the MISILAB (i.e., the MISILAB was not linked to live aircraft) on 29-30 October 1997. These provided data for validating the live mission results.

The results of evaluating the test objectives are as follows.

- The MISILAB missile performance was valid for its target presentation, and the target presentation accurately represented the live target. Also, the umbilical and RDL messages provided to the MISILAB missile accurately replicated those generated by the shooter 98% of the time. The validation process revealed the following:
  - The MISILAB standalone simulations of the OP-612 engagement were valid. This reaffirmed the expectation that the MISILAB HWIL simulation in a standalone configuration would provide valid AMRAAM results.
  - The validation process compared the missile performance results of a single linked run to the envelope of 25 MISILAB standalone runs which all used the same launch conditions, umbilical and RDL messages, and target trajectory as the linked runs. Four linked runs were selected for validation.
  - The validation process was applied to the following MISILAB output parameters:
    - Missile trajectory.
    - Missile telemetry signals.
    - Missile timelines.
  - The validation process showed that the MISILAB HWIL facility provided proper and valid responses to its inputs. All of the MISILAB output parameters evaluated were assessed to be valid. The conclusion was that the LFP ADS configuration provided valid AMRAAM data and a valid testing environment for an integrated launch aircraft/missile weapon system.
- The LFP ADS configuration would be able to accomplish some of the AMRAAM test objectives, within certain limitations.
  - The limitations reduce the variety of scenarios which could be evaluated. However, these limitations were due to the range and facilities used, as well as the ADS implementation.

- The TDP was able to provide the required accuracy of aircraft TSPI. The TDP solutions were estimated to be accurate to within 1-3 meters in position and 1 m/s in velocity. These values met the MISILAB accuracy requirements.
  - -- The use of multiple TSPI inputs resulted in robust TDP performance. In particular, periodic GPS dropouts did not significantly degrade the accuracy of the position solution, because the TDP used the accurate INS data to propagate the solution between GPS updates.
- The aircraft entity state data were properly aligned to the MISILAB reference frame. Also, the missile was properly located on the shooter prior to launch
- The data required to drive the MISILAB simulation were properly synchronized for input.
  - -- Variable processing delays resulted in aircraft entity state data and the umbilical and RDL messages arriving at the MISILAB in an unsynchronized fashion.
  - -- Buffering and time alignment of the data resulted in synchronized inputs.
  - -- The shooter and target entity state data were synchronized to each other for input into the MISILAB simulation to within the accuracy of the entity state data time tag, ±2 milliseconds.
  - -- The aircraft entity state data were synchronized to the MISILAB simulation frame rate by interpolating the 10 Hz TDP output at the 600 Hz frame rate. This was a very effective technique for synchronizing the shooter and target entity state data to each other and to the simulation, and the degree of synchronization achieved was limited only by the interpolation rate accuracy and stability.
  - -- The umbilical and data link messages were buffered and synchronized to the entity state data by the AASI to within 20 milliseconds. This could result in an insignificant difference between the target position indicated in an umbilical/RDL message and that from the entity state data (~5 meters).
- Significant latencies resulted from the LFP configuration.
  - -- Processing of the TSPI data by the TDP and by a post-TDP smoother resulted in latencies of about 2.4 seconds for aircraft entity state data arriving at the MISILAB. Smoothing of the TDP solution was required for proper MISILAB simulation performance.
  - -- Buffering of the data for synchronization to the MISILAB simulation resulted in an additional 600 milliseconds of latency.
  - -- Transmission delays made an insignificant contribution to the total latency.
  - -- Total latency of the missile simulation was about 3 seconds relative to the live aircraft.
- The ADS network provided ample bandwidth.
  - -- Only about 1% of the T-3 and 2-3% of the T-1 bandwidth was utilized.
- There were no significant ADS-induced errors.
- The DIS PDUs used were adequate for data exchanges.
- There was good availability of the LFP testing configuration and no wide area network failures.
- The test control procedures worked well, in general, but there were some problems.
  - -- Decision makers did not have full situational awareness, preventing timely and informed decisions when problems arose during the missions. Better communications can mitigate this in the future.

LFP UTILITY CONCLUSIONS

The results of LFP testing support the following conclusions on the utility of the LFP ADS configuration.

- The LFP ADS configuration has utility for missile weapon/launch aircraft system T&E.
  - The configuration successfully ran integrated scenarios/profiles among linked participants.
  - This configuration can be used for discrepancy/deficiency resolution, especially when there are interface issues/problems between/among weapon systems (e.g., the aircraft radar, mission computer, stores management system, and the missile). This includes troubleshooting problems which prove to be difficult to replicate, particularly those that appear in flight tests but are not readily duplicated in standalone laboratory testing.
  - The linked configuration permits the HWIL missile to respond to actual pre- and post-launch weapon system inputs, instead of relying on standalone "canned" inputs, in a much more operationally realistic environment.
  - The use of highly accurate TSPI data permits more accurate and thorough evaluations of the accuracy of umbilical/RDL messages than was possible under previous testing.

- The LFP ADS configuration has utility for rehearsal and refinement of live fire test scenarios.
  - Pilot training and rehearsals of live missile firings requiring difficult and/or precise launch conditions could be accomplished using this configuration. ADS could assist in doing the live fire test right the first time.
  - The LFP ADS configuration gives immediate results on the missile performance for a given scenario and can be used as a risk reduction tool before live fire missions.

- The LFP ADS configuration permits more efficient testing.
  - Quick-look results are available immediately after each pass, and the analysts can determine if the pass objectives were accomplished, if the proper profile was executed, and if valid data were obtained. This timely determination allows decisions to be made during the mission on the conduct of subsequent passes (e.g., if the missile did not appear to perform properly, the pass can be repeated).

- The LFP ADS configuration does not have utility for terminal engagement studies involving closed-loop interactions between the missile and the target (missile and target respond to each other).
  - Latencies were much too large for this application.
  - Feedback loops to the live target would have to be developed.
  - This is not a serious limitation, since nearly all live fire missile testing is open loop. In particular, AMRAAM does not have a closed-loop testing requirement.